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INTEGRATION OF FMEA AND BAYESIAN NETWORK METHODS FOR RISK ASSESSMENT OF COMPONENTS DELAY IN FERRY SHIP CONSTRUCTION

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Abstract

Construction of new ships in Indonesia. In this case study, the construction of a 600 DWT Ro-Ro ferry. The 600 DWT Shipbuilding Project involves various risks that may affect the schedule and results. A risk assessment involving the quality control team, project lead, and production management is carried out to identify and quantify the level of risk and its consequences.

The results of this assessment assist in understanding and managing project risk, stress the importance of communication and coordination between teams, and enable better contingency planning and more effective project management. The FMEA calculation method is used to identify potential failure modes, determine the impact of each failure, and calculate a risk score based on the probability and effect of each failure. The Bayesian method updates the likelihood of failure based on new data that appears during the shipbuilding process. FMEA data is taken from the RPN (Risk Priority Number) at the Occurrence value, then weighted against the list of risks. Most risks are considered 'rare' in terms of likelihood and 'insignificant' in terms of consequence, indicating that despite potential obstacles, the impact on the project is expected to be minimal. However, several risks with 'minor' effects have been identified, highlighting the importance of effective risk planning and mitigation.

The integration of this method still needs to be improved, especially in the shipping industry. This method can be developed by making applications to control the procurement of materials at the beginning and during the construction and evaluation process at the end. The effort to make the ship construction timely according to the contract answers the shipbuilding challenges that often occur in developing countries.

Keywords: Bayesian network, ferry, FMEA, integration method, risk assessment, ship construction.

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1. Introduction

Ferry construction is a complex process and requires various components to arrive on time to ensure the efficiency and effectiveness of the process. Delays in the arrival of components can significantly impact the ship's overall schedule and final quality [1]. Let's consider identifying technologies for achieving productivity as critical to the shipbuilding process. A practical risk assessment is urgently needed to manage and mitigate the impact of delays [2]. In this study, it is proposed a new approach to risk assessment by integrating two proven effective methods: Failure Mode and Effects Analysis (FMEA) and the Bayesian method. FMEA has been used extensively in industry to identify and assess risks based on failures that may occur in the system [3]. The probabilistic risk assessment of the shipbuilding industry using the Bayesian method will involve a comprehensive examination of the uncertainties and risks inherent in the shipbuilding process. The core finding of this study will be an evidence-based quantification of these risks, enabling more informed decision-making and risk management strategies within the industry [4]. The Bayesian method allows a more flexible and robust risk assessment by considering the uncertainty and variation in the data [5]. Although these two methods have been widely used separately, recent studies have shown that combining the two can provide a more comprehensive and accurate risk assessment. This approach offers a more sophisticated and nuanced analysis by integrating various fuzzy logic methodologies, proving its efficacy in a conference setting, thus setting a precedent for future research [6]. However, the combined use of these methods in the context of ferry construction has yet to be explored, and this is the focus of our research.

The ferry building is a highly structured process with many interacting variables. Delays in the delivery of ship components can affect many later stages in the building process, including work scheduling, resource efficiency, and overall costs. This framework uses probabilistic graphical models to incorporate numerous environmental, infrastructural, and socioeconomic factors, thus offering a comprehensive flood risk evaluation [1]. Therefore, managing these risks is critical to the success of a shipbuilding project.

The FMEA method has been used in various industries, including shipbuilding, for risk identification and assessment. FMEA helps identify potential failure modes and their effect on the system as a whole [3]. However, this method has limitations, especially in considering the uncertainty and variation in the data. On the other hand, the Bayesian approach overcomes some of these limitations by allowing for a more flexible and robust risk assessment. This method enables better decision-making under conditions of uncertainty by updating probabilities based on available data [5], transforming qualitative data into a format suitable for quantitative analysis. This method can efficiently manage uncertainty and improve the reliability of systems analysis, thus enhancing decision-making processes in quality and reliability engineering [7]. The VIKOR weighting and fuzzy combination method in FMEA enables a more accurate and efficient risk assessment in prioritizing failure modes [8].

Various risk evaluation approaches in FMEA have been developed, providing valuable insights into recent trends and developments in risk evaluation [9]. Introduces a risk evaluation in FMEA based on D numbers theory, a new methodology that generalizes Dempster-Shafer (D-S) theory and allows for expressing more types of uncertainty. This method leverages fuzzy set theory and evidence theory to address uncertainty and provide a more comprehensive and flexible evaluation. This approach improves the traditional FMEA by enhancing its ability to deal with complex systems and uncertain information, which is particularly useful in applied soft computing [10]. Applying D numbers theory to FMEA potentially enhances the precision and flexibility of risk evaluation processes [11]. However, more research still needs to explore integrating FMEA and Bayesian methods in shipbuilding. This study aims to fill this gap by evaluating the potential of this integrated approach in assessing the risk of the late arrival of components in ferry construction.

2. Material and Method

A significant problem for the Indonesian and several other countries shipping industry is that about 70–80 % of the parts onboard ships are imported parts. Using imported parts is more expensive, as imports are subject to import duties and tariffs. On the other hand, it takes time to order imported parts, which lengthens the ship's manufacturing period, and it can take up to eight months, especially for main engine parts [12, 13]. Technological innovation must be further developed to support timely development programs, reduce costs associated with developmental delays, and realize the country's ideals of equitable social development and social justice [14]. Risk assessment using FMEA methodologies in the maritime industry [15–17]. Articles risk assessment using Bayesian Network – BN in papers [4, 15, 18–20]. There is a journal that combines FMEA-BN [21]. In this article, let's develop this method and apply it to construct new ships at one of Indonesia's domestic shipyards.

This study is expected to contribute to the shipbuilding industry by providing a better understanding of how to manage and mitigate the risks associated with the late arrival of components. The results are also expected to provide valuable insights for further research. By leveraging this integrative approach, let's hope to provide new insights into managing and mitigating the risks associated with the late arrival of components in ferry construction.

FMEA is used as a first step in risk assessment. This process involves identifying potential failure modes, the effects of these failures, and the causes of failure [3]. In traditional FMEA, the risk score is obtained by multiplying the values of three factors: severity, incidence, and detection [22]. In FMEA, each failure mode, effect, and cause are scored based on severity (S), occurrence (O), and detection (D). This score is usually given on a numerical scale of 1 to 10. The score is then multiplied to produce a risk score (Risk Priority Number, RPN): In this context, the failure mode is the delay in the arrival of the component, and the effects and causes of failure are analyzed in this context. Each failure mode, impact, and causality are scored based on severity, occurrence, and detection. The score is then multiplied to produce a risk score (Risk Priority Number, *RPN*):

$$RPN = \text{Severity}\cdot\text{Occurrence}\cdot\text{Detection}, \quad (1)$$

where S is the severity score or impact of the failure; O is the event score, or how often the failure occurs; D is the detection score or how easily a failure can be detected.

Once the *RPN* score is calculated, the Bayesian method updates the risk assessment based on available data. Risk assessment is carried out using Bayes' theorem, which allows the calculation of posterior probabilities based on prior probabilities and likelihoods [5]:

$$P(A|B) = [P(B|A)\cdot P(A)]/P(B), \quad (2)$$

where $P(A|B)$ is the posterior probability, or the probability of A, given that B occurs; $P(B|A)$ is the likelihood or probability of B, given that A occurs; $P(A)$ is the prior or initial probability of A before data B is known; $P(B)$ is the proof, or total probability, of B.

Integrate FMEA and the Bayesian method. The *RPN* score from FMEA is used as input for Bayesian calculations. This score is used as a prior probability in Bayesian calculations and then updated based on available data to produce a more accurate risk assessment [5]. The selection and collection of data is an essential step in this research. Data on component arrivals and the impact of delays on the ferry construction process was collected from various sources, including internal records, project reports, and interviews with the project manager and field workers. This data is then used to determine potential failure modes, effects, and causes in the context of FMEA, as well as evidence in Bayesian calculations. After the risk score has been calculated using an integrated approach, further analysis and interpretation is carried out. Risk score includes identifying key areas, analyzing trends, and determining potential mitigation measures. In addition, the resulting risk assessments were compared with those produced by FMEA, and the Bayesian method was used separately to demonstrate the advantages of this integrated approach. Research results validation, this integrated approach was also applied to other cases in ship construction, and the results were compared. In addition, this study also cross-checked the data with previous data and compared the results to prior studies that used FMEA and Bayesian methods separately. Publications on the use of separate methods in the maritime and shipbuilding industries can be seen in our previous paper [21].

The FMEA method is used to identify potential failure modes, determine the impact of each failure, and calculate a risk score based on the probability and impact of each failure. In the context of shipbuilding, failure modes can include delays in the delivery of components, errors in the construction process, or other problems that could affect the shipbuilding schedule. Presents an integrated risk assessment model for cargo manifold process on tanker ships, incorporating the Failure Mode, Effects and Criticality Analysis (FMECA) extended with Dempster-Shafer theory and a rule-based Bayesian network approach. This research provides a novel framework for managing and reducing the risk associated with maritime cargo operations. The study demonstrates the effectiveness of integrating various theories and methods to handle complex, uncertain, and dynamic environments, thus improving process safety and environmental protection in marine contexts [23].

Meanwhile, the Bayesian method updates the probability of failure based on new data during the shipbuilding process. This method allows real-time adjustment of the probability of failure based on the latest information to provide a more accurate picture of the risks faced. The

VIKOR method is a multi-criteria decision-making technique designed to handle situations where decision-makers cannot express their preferences precisely [8]. This integrated approach permits capturing the complex interactions between different system components, and the dynamic nature of system performance over time. The findings from this research contribute to improving safety and efficiency in mechanical engineering and related industrial operations [24].

Based on the provisions of The Australia/New Zealand Risk Management Standards (AS/NZS4360:1999), the criteria for probability (likelihood) and consequences can be seen in **Tables 1, 2** below.

Table 1
Definition of likelihood criteria

Likelihood	Likelihood description
Rare	<1 % of total working days
Unlikely	1–5 % of total working days
Possible	5–25 % of total working days
Likely	25–60 % of total working days
Almost Certain	>60 % of total working days

Table 2
Definition of consequences criteria

Consequences	Description consequences
Insignificant	Time wasted <10 days
Minor	Time wasted 10 to 20 days
Moderate	Time wasted 20 to 50 days
Major	Time wasted 50 to 100 days
Catastrophic	Time wasted >100 days

3. Results and Discussion

The case study in this research was carried out on a 600 DWT ferry construction project at a shipyard, PT XY. This project involves four main network model groups: Hull Construction, Machinery, Electrical, and Other Equipment. Currently, the project is ongoing, so there is a need for immediate risk anticipation, especially in the material and machinery group. Risk analysis in that the material group significantly influences the production process and design revisions.

Therefore, calculating the probability of failure in each subprocess becomes very important. This probability is calculated using the Quality Control (QC), Project Lead, and Production Manager assessments. The following is the calculation of the probability of failure for each subprocess.

The primary network model in this study was developed based on the principle that the shipbuilding process is divided into four main parts: Hull Construction, Machinery Outfitting, Electrical Outfitting, and Other Equipment Procurement. These four processes are closely interrelated, so delays in one process can cause delays in other processes, which in turn hampers the entire shipbuilding process. The weight values for each process are obtained from shipbuilding companies' data. It is important to emphasize that these weights may differ for different shipbuilding processes and shipbuilding companies, depending on each company's database. The main focus in developing this network model is on the process of building a 600 DWT ferry. The case studies used in this research involve various companies throughout Indonesia.

Fig. 1 shows the weight and probability of variance (VAR) and the Bayesian probability of the four main components in constructing a 600 DWT ferry: Hull Construction, Machinery, Electrical, and Other Equipment. These weights and probabilities are assessed by three different entities: Quality Control (QC), Project Leadership Section (Project Lead), and Production Section.

Hull Construction (H): this component has the highest weight, 31.62 %, and the VAR probability ranges from 7.905 to 9.636. The Bayesian probability for this component is between 0.31

and 0.38. Hull Construction is a critical component in shipbuilding and has a significant potential risk of failure. Machinery (M): this component weighs 27.39 % with a VAR probability between 5.371 and 6.849. Bayesian probabilities range from 0.21 to 0.27. Although the weight is slightly lower than Hull Construction, Machinery still has a high potential risk of failure. Electrical (E): this component weighs 18 % with a VAR probability between 3.506 and 4.500. Bayesian probabilities range from 0.14 to 0.18. The Electrical component's failure risk is lower than the previous two components. Other Equipment: this component weighs 24.45 % with a VAR probability between 6.111 and 7.106. Bayesian probabilities range from 0.24 to 0.28. Even though it is included in the «Other» category, this component still carries significant potential risks.

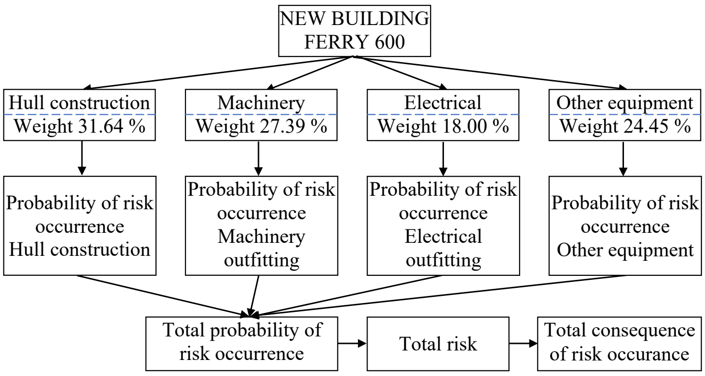

Fig. 1. The main network model of the Bayesian Network assessment on the new building Ferry 600 DWT

Fig. 2 shows that each component has a different potential risk of failure, with Hull Construction and Machinery showing the highest probability. Risk management should focus more on these two components in this 600 DWT ferry construction project.

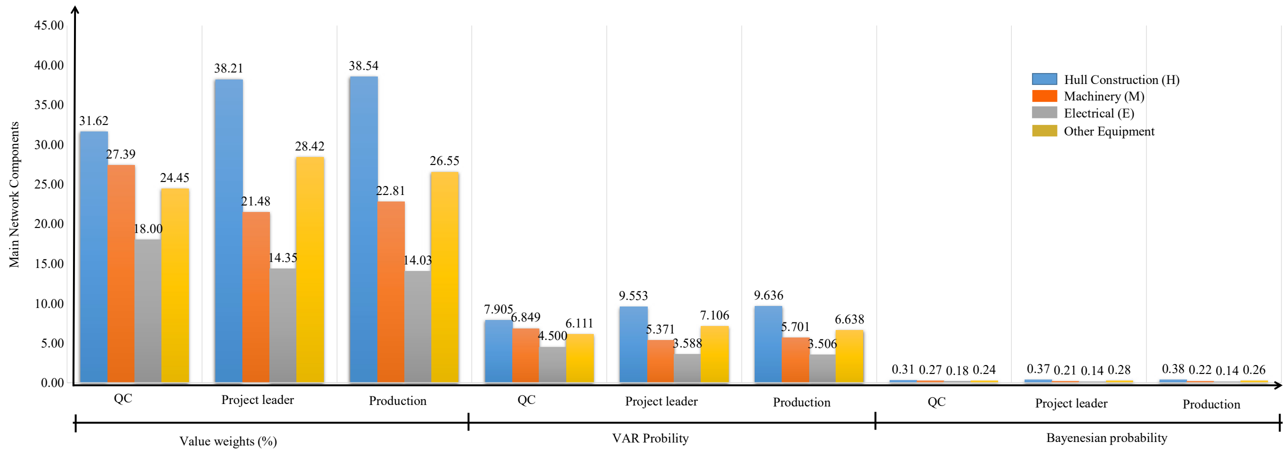

Fig. 2. Weight and Probability of Variance (VAR), Bayesian Probabilities of the Four Main Components in the Construction of the 600 DWT Ferry

The probability rating of failure of various components in the construction of a ferry is based on Quality Control (QC) assessment. Most of the delays were related to Hull Construction and Other Equipment, with some components in the Machinery and Electrical categories also having a high probability of failure. Delays in the delivery and installation of critical components such as airtight doors, window boxes, vents, panel materials, and wiring have a high probability of failure. Quality control assessment is shown in **Fig. 3** below.

The ranking of the probability of failure is based on the evaluation of the Project Leader, for various components in the construction of the ferry. It is shown in **Fig. 4**.

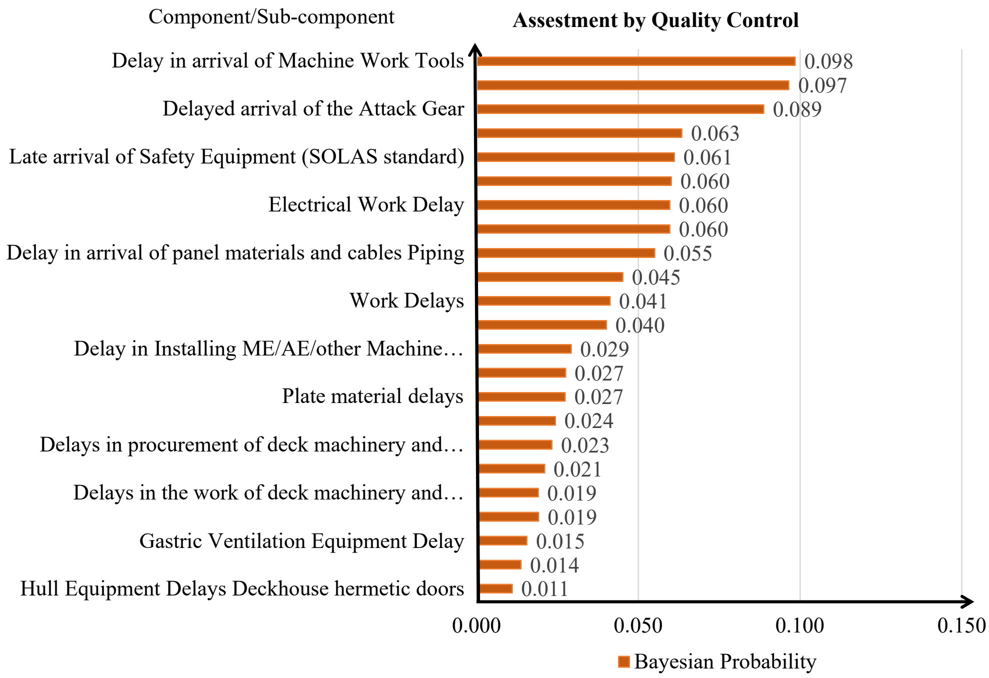

Fig. 3. Failure rating based on Quality Control rating

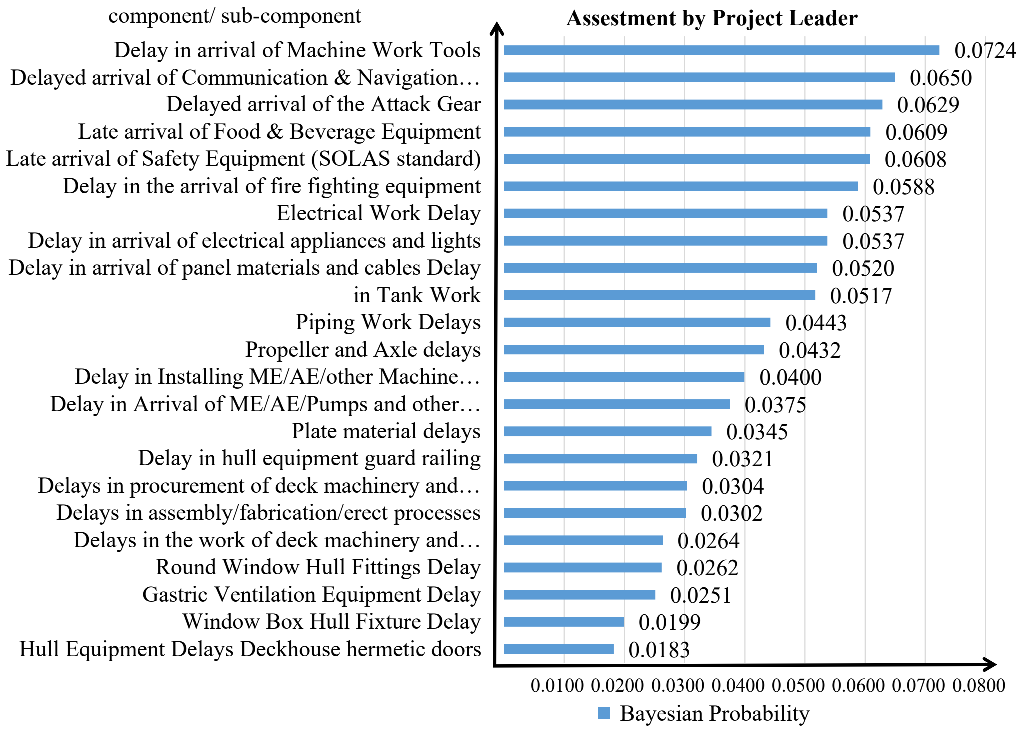

Fig. 4. Failure rating based on Project Lead's rating

Most of the delays recorded relate to procuring and installing hulls, machinery, or other equipment. Delivering and installing airtight doors, window boxes, vents, panelling materials, and wiring includes delays. Further delays have delays in electrical machinery and equipment, such as plumbing and tank work, and delays in the arrival of safety equipment and food and beverage equipment.

Fig. 5 shown the probability of failure rating is based on the Production Manager's assessment of the various components in the construction of the ferry. This data indicates that the Production Manager identified multiple risks associated with delays in delivering and installing critical components, including airtight doors, window boxes, ventilation, panel materials, and wiring. In addition, delays in the procurement and installation of machinery and electrical equipment, such as pipe works and tank works, and delays in the arrival of safety equipment and food and beverage equipment, were also identified as significant risks. In this context, the Production Manager views delays in the delivery and installation of equipment and materials as a significant risk factor in shipbuilding projects. Therefore, effective risk management and close supervision are necessary to ensure projects are on schedule and avoid delays.

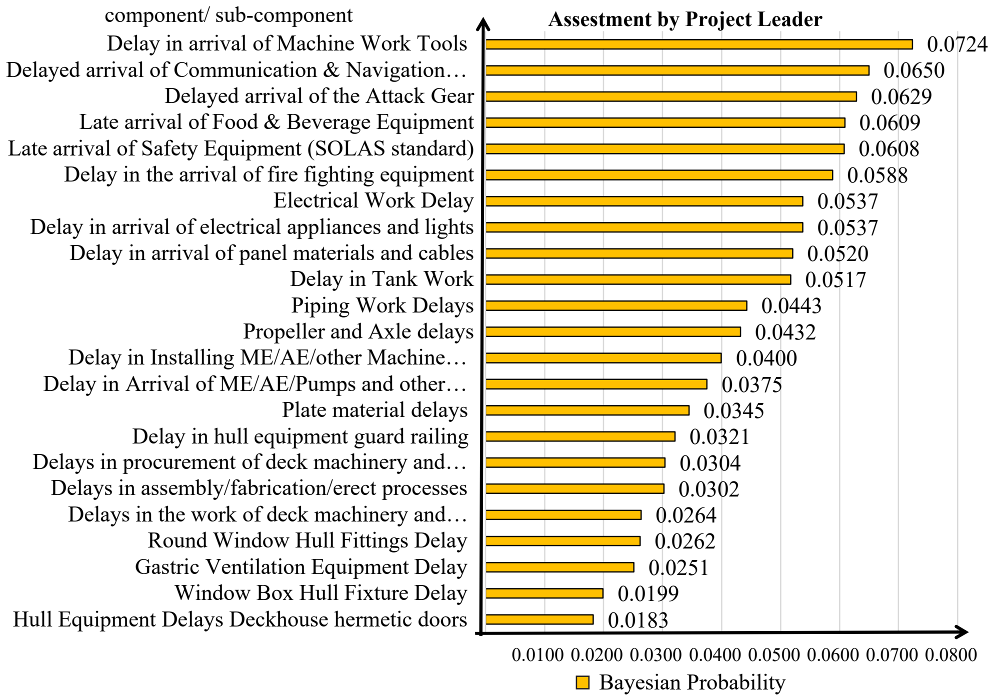

Fig. 5. Failure rating based on Production Manager's assessment

Risk Analysis. The ranking of the probability of occurrence of failure and the frequency of occurrence for each process and sub-process in each of the collected network models. Based on the probability table in each section, namely QC, Project Leader, and Production Manager. Observations were made during the research activities, and it was assumed that they were only for one month of events. Determine the failure rate every day.

The consequence is the amount of work delay or wasted time caused by each source of risk. Calculating each event's mean/average delay, the factor times the consequences are obtained, as shown in **Fig. 6**.

In this 600 DWT ferry construction project, the initial contract was valid for one year, from 1 March 2018 to March 2019. However, in practice, new vessels could be delivered in August 2019. There was a delay of five months from the specified schedule in the contract. The calculation of the probability of failure and the impact of the failure is assumed to take place from 1 March 2018 to August 2019, which is 18 months. To calculate the consequences of a month's delay in work, it is necessary to consider the number of hours wasted. This amount is calculated by dividing the total wasted working hours by 12 hours worked in a day, based on the assumption that the maximum working hours in a day is 12 hours.

The results of calculating the probability of failure and the impact of failure are presented in the table ranking the risk of delays in the sub-process, presented in **Table 3** below.

Then let's map each position to the probability of failure and the impact of losses. Next, let's determine the risk rating for each section, and map it into the risk matrix. Discussion of probability & consequences based on the provisions of The Australia/New Zealand Risk Management Standards (AS/NZS4360:1999), probability criteria (Likelihood), and consequences (Consequences).

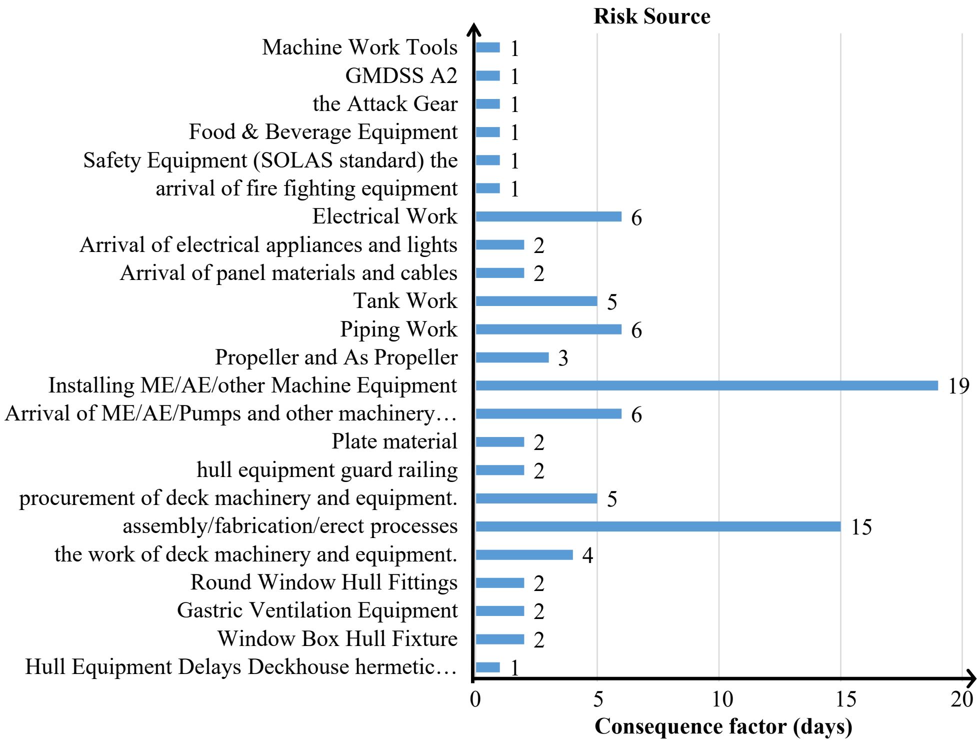

Fig. 6. Consequence times factor value

Table 3
Network model sub-process delay risk rating

Source of Risk	CTF (Days)	Quality Control		Project Lead		Production	
		Lkd	Consq/event (days)	Lkd	Consq/event (days)	Lkd	Consq/event (days)
Hull Equipment Delays Deckhouse hermetic doors	1.00	1.00	0.20	0.92	1.84	1.06	2.12
Window Box Hull Fixture	2.00	2.00	0.49	1.06	2.13	0.97	1.93
Gastric Ventilation Equipment	2.00	2.00	0.56	0.70	1.40	0.62	1.24
Round Window Hull Fittings	2.00	2.00	0.69	0.41	0.41	0.33	0.33
The work of deck machinery and equipment	4.00	4.00	1.51	0.79	1.59	0.68	1.35
Assembly/fabrication/erect	15.00	15.00	7.38	0.48	0.95	0.47	0.95
Procurement of deck machinery and equipment	5.00	5.00	2.63	0.44	2.22	0.55	2.74
Hull equipment guard railing	2.00	2.00	1.44	0.75	2.98	0.93	3.72
Plate material delays	2.00	2.00	2.17	0.83	12.38	0.97	14.51
ME/AE/Pumps and other machinery equipment	6.00	6.00	10.63	1.14	6.84	1.30	7.81
Installing ME/AE/ME/AE/another Machine Equipment	19.00	19.00	20.90	0.82	15.56	0.80	15.14
Propeller and AS	3.00	3.00	2.23	0.47	1.40	0.54	1.63
Piping Work	6.00	6.00	6.45	0.67	4.05	0.78	4.67
Tank Work	5.00	5.00	5.37	0.53	2.65	0.72	3.60
Panel materials and cables	2.00	2.00	3.47	0.98	1.97	0.94	1.87
Electrical appliances and lights	2.00	2.00	3.19	1.20	2.40	1.10	2.19
Electrical Work	6.00	6.00	4.88	0.52	3.11	0.58	3.47
Firefighting equipment	1.00	1.00	0.99	1.22	1.22	1.09	1.09
Safety Equipment	1.00	1.00	1.14	1.26	1.26	1.17	1.17
Food & Beverage Equipment	1.00	1.00	0.34	0.58	0.58	0.36	0.36
Attack Gear	1.00	1.00	0.49	0.65	0.65	0.47	0.47
GMDSS A2	1.00	1.00	0.42	0.80	0.80	1.13	1.13
Machine Work Tools	1.00	1.00	0.44	0.78	0.78	0.45	0.45

The results of mapping the likelihood and consequence levels of quality control, project leaders, and production assessment can be seen in **Table 4** below.

Table 4
Mapping the likelihood level and consequences level of the 600 DWT ferry by Quality Control (QC), Project Lead, and Production Assessment

Source of Risk	Level Likelihood			Level Consequences		
	QC	Project Leader	Pro-duction	QC	Project Leader	Production
Hull Equipment Delays Deckhouse hermetic doors	Rare	Rare	Unlike	Insignificant	Insignificant	Insignificant
Window Box Hull Fixture	Rare	Unlike	Rare	Insignificant	Insignificant	Insignificant
Gastric Ventilation Equipment	Rare	Rare	Rare	Insignificant	Insignificant	Insignificant
Round Window Hull Fittings	Rare	Rare	Rare	Insignificant	Insignificant	Insignificant
Work of deck machinery and equipment.	Rare	Rare	Rare	Insignificant	Insignificant	Insignificant
Assembly/fabrication/erect processes	Rare	Rare	Rare	Insignificant	Insignificant	Insignificant
Procurement of deck machinery and equipment.	Rare	Rare	Rare	Insignificant	Insignificant	Insignificant
Hull equipment guard railing	Rare	Rare	Rare	Insignificant	Insignificant	Insignificant
Plate material	Unlike	Rare	Rare	Insignificant	Minor	Minor
Arrival of ME/AE/Pumps and other machinery equipment	Unlike	Unlike	Unlike	Minor	Insignificant	Insignificant
Installing ME/AE/other Machine Equipment	Unlike	Rare	Rare	Mode	Minor	Minor
Propeller and As Propeller	Rare	Rare	Rare	Insignificant	Insignificant	Insignificant
Piping Work	Unlike	Rare	Rare	Insignificant	Insignificant	Insignificant
Tank Work	Unlike	Rare	Rare	Insignificant	Insignificant	Insignificant
Arrival of panel materials and cables	Unlike	Rare	Rare	Insignificant	Insignificant	Insignificant
Arrival of electrical appliances and lights	Unlike	Unlike	Unlike	Insignificant	Insignificant	Insignificant
Electrical Work	Rare	Rare	Rare	Insignificant	Insignificant	Insignificant
Arrival of firefighting equipment	Rare	Unlike	Unlike	Insignificant	Insignificant	Insignificant
Safety Equipment (SOLAS standard)	Unlike	Unlike	Unlike	Insignificant	Insignificant	Insignificant
Food & Beverage Equipment	Rare	Rare	Rare	Insignificant	Insignificant	Insignificant
Attack Gear	Rare	Rare	Rare	Insignificant	Insignificant	Insignificant
GMDSS A2	Rare	Rare	Unlike	Insignificant	Insignificant	Insignificant
Machine Work Tools	Rare	Rare	Rare	Insignificant	Insignificant	Insignificant

Quality Control. The **Table 4** above shows the risk evaluation of various aspects of the production process of ships with a capacity of 600 DWT based on assessments from the quality control (QC) department. Each risk is assessed based on likelihood and consequences (impact per event), expressed in days. Furthermore, these two factors are given a level or level based on how much they affect the production process. Here is an explanation of some of the entries.

Hull Equipment Delays Deckhouse hermetic doors: this risk has a likelihood of 0.20 and consequences of 0.20 days. In the event of a delay in hull fitting, the impact may not be significant. This point is also reflected in the likelihood and consequences levels, marked as «rare» and «insignificant», respectively, indicating that the risk is rare and the impact is insignificant.

Delay in Installing ME/AE/other Machine Equipment: this risk has a likelihood of 1.10 and consequences of 20.90 days. Although this likelihood is rated as «unlikely», the high consequences are labelled «moderate», indicating that the impact could be pretty significant if this risk were to occur.

In general, this table reflects that most of the identified risks have a low likelihood («rare» or «unlikely») and an insignificant impact («insignificant»). However, there are some risks with higher impact («minor» or «moderate»), even though their likelihoods are still relatively low. Indicates that project management should prioritize mitigating and managing these risks to ensure smooth production processes.

Project Lead. **Table 4** above also presents a risk evaluation of various aspects of the 600 DWT ship production process based on the assessment of the project lead. Here is an explanation for some of the entries:

Plate material delay: this risk has a likelihood of 0.92 and consequences of 2.00 days. It is indicated by the likelihood and consequences levels, marked as «rare» and «insignificant», respectively, indicating that the risk is rare and the impact is not significant. Project lead assessment means that if there is a delay in the delivery of plate material, the impact may be insignificant (insignificant).

Delay in Installing ME/AE/other Machinery: this risk has a likelihood of 0.82 and consequences of 19.00 days. Although this likelihood is rated as «rare», these high consequences are labelled «minor», indicating that the impact could be pretty significant if this risk were to occur.

In general, this table reflects that most of the identified risks have a low likelihood («rare» or «unlikely») and an insignificant impact («insignificant»). However, some risks have higher («minor») impacts, although their likelihoods are still relatively low. The project lead must mitigate and manage these risks to ensure a smooth production process.

Production. **Table 4** results from production management's assessment of the risks of constructing a 600 DWT ship. Each row represents a potential source of risk, followed by the two-primary metrics: likelihood (likelihood of occurrence) and consequences (effect or impact per event, measured in days). Likelihood and consequences are then categorized into levels based on their severity. The likelihood level includes «rare» and «unlikely», and the Consequences level includes «insignificant» and «minor».

Delay in plate material: this risk has a likelihood of 1.06 and consequences of 2.00 days. The likelihood is considered «unlikely», and the impact is considered «insignificant», meaning that if this occurs, the impact on the overall production schedule is considered insignificant.

Delay in Installing ME/AE/other Machinery: this risk has a likelihood of 0.80 and consequences of 19.00 days. Although these likelihoods were considered «rare», the consequences were assessed as «minor», indicating that if this were to occur, the impact on the production schedule could be considered significant.

Overall, this assessment is essential for understanding how production management perceives potential risks in the production process and assessing the potential impact. The results can be used to develop risk mitigation strategies and contingency plans.

The case study regarding the construction of a 600 DWT ferry at PT XY revealed various risks of delays in multiple aspects of the project. An assessment conducted by the Quality Control (QC) team found that the consequences of delays in all risk sources were generally less than ten days. However, there are exceptions regarding the Arrival of ME/AE/Pumps and other Machinery Equipment, which are delayed between 10 to 20 days, and delayed install ME/AE/other machinery equipment between 20 to 50 days.

Meanwhile, the risk assessment conducted by the project leader also shows that, in general, the delay is less than ten days for all sources of risk. However, there is a risk of delays in the assembly/fabrication/erecting process and installing ME/AE/other machine equipment, which experience delays of between 10 and 20 days.

From a production perspective, delays are less than ten days, except for assembly/fabrication/erect Process Delays and ME/AE/other machinery equipment install delays, which experience 10 to 20 days. Risk assessment of the three departments, it can be concluded that the three risk sources, namely delays in the Arrival of ME/AE/Pumps and other Machinery Equipment, delays in Installing ME/AE/Other machinery equipment, and delays in the Assembly/Fabrication/Erection Process have a significant impact on project delay for three months.

Assessments by the 3 sections mentioned above can still be added, one of which is an assessment from the purchasing department, assessing inspectors and other parties involved in the construction of new ships. Risk assessment can be done by comparing the S-curve with the ship construction process, from procurement to the installation of materials on the ship.

The mitigation carried out will help decision-making further so that the risk of delays in ship delivery is reduced.

This research topic still has the potential to be developed. Efforts to increase ship delivery time require cooperation from various parties, development in aspects of work quality, inspection, and certification, as well as other related aspects.

The author is developing an application to control the procurement of materials and work.

4. Conclusions

Based on the results of the assessment carried out by the Quality Control team, project leaders, and production management, the following are some of the main conclusions.

Based on the case study of the construction of a 600 DWT ferry at PT XY, the risk assessment of the QC, project lead, and production department revealed several significant sources of risk related to delays in the project. In general, delays of less than ten days were found for most risk sources. However, more significant delays occurred in ME/AE/Pumps and other Machinery Equipment Delays (10–20 days), ME/AE/other Machinery Equipment Install Delays (20–50 days), and assembly/fabrication/erect Process Delays (10–20 days). This study concludes that the three sources of risk significantly affect the delay in the ferry construction project for three months. Therefore, an effective risk mitigation and management strategy is required to address these risk sources to minimize their impact on the project schedule and increase the chances of success of the 600 DWT ferry building project.

Perception of Risk there is some variation in how various stakeholders perceive the level of risk from various potential sources. However, in general, most risks are considered 'RARE' regarding the likelihood of occurrence and 'INSIGNIFICANT' regarding impact. Some of the risks assessed have a more significant impact than others, such as 'Delays in the process of assembly/fabrication/erection and 'Delays in Installing ME/AE/other Machinery Equipment.' These risks are considered 'MINOR' in terms of their impact, indicating that they could significantly impact the production schedule if they occur.

Conflict of Interest

The authors declare that there is no conflict of interest in relation to this paper, as well as the published research results, including the financial aspects of conducting the research, obtaining and using its results, as well as any non-financial personal relationships.

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The study was performed without financial support.

Data availability

Data will be made available on reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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